(51) Int. Cl.: B 28 c

BUNDESREPUBLIK DEUTSCHLAND

DEUTSCHES PATENTAMT

(52) Deutsche Kl.: 80 a, 7/45

(10)
(11) **Offenlegungsschrift 1 921 681**

(21) Aktenzeichen: P 19 21 681.0

(22) Anmeldetag: 28. April 1969

(43) Offenlegungstag: **5. November 1970**

Ausstellungspriorität: —

(30) Unionspriorität

(32) Datum: —

(33) Land: —

(31) Aktenzeichen: —

(54) Bezeichnung: Verfahren zum Messen und Steuern des Wassergehalts im Frischbeton

(61) Zusatz zu: —

(62) Ausscheidung aus: —

(71) Anmelder: Foth, Dipl.-Ing. Joachim, 8000 München

Vertreter: —

(72) Als Erfinder benannt: Erfinder ist der Anmelder

Benachrichtigung gemäß Art. 7 § 1 Abs. 2 Nr. 1 d. Ges. v. 4. 9. 1967 (BGBl. I S. 960): —

DT 1 921 681

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halt der Betonmischung das Meßergebnis beträchtlich beeinflußen und bis zur Unbrauchbarkeit verfälschen können. Das gleiche gilt für ein anderes Verfahren, bei dem die Veränderung der Dielektrizitätskonstanten mit dem Feuchtigkeitsgrad durch kapazitive Messungen erfaßt wird. Bei einem weiteren Verfahren werden die Konsistenz und die plastischen Eigenschaften der Mischung, die sich mit dem Wassergehalt ändern, durch Messung des Widerstandes der Mischung gegen eine Verformung für die Beurteilung des Wassergehaltes herangezogen. Dieser Widerstand drückt sich in einer mehr oder weniger großen Leistungsaufnahme des Mischermotors aus. Die Leistungsaufnahme des Mischermotors ist aber auch von Netzspannungsschwankungen und von zufälligen Störungen, wie Kieskornklemmung oder Maschinenfehler abhängig. Daher liefert dieses Verfahren ebenso wie die erwähnten anderen beiden bestenfalls nur grobe Anhaltswerte.

Es ist auch schon bekannt, den Feuchtigkeitsgehalt der Zuschlagstoffe v o r ihrer Verarbeitung mit Zement und Wasser zu ermitteln und mit den gefundenen Meßwerten die Wasserzugabe zur Mischung zu steuern. Bei diesem Verfahren ist es zur Erzielung eines zuverlässigen Ergebnisses jedoch erforderlich, sämtliche Korngruppen getrennt zu messen, was wegen der großen Anzahl und der Kompliziertheit der dann notwendigen Geräte unwirtschaftlich ist.

Der Erfindung liegt daher die Aufgabe zugrunde, den tatsächlichen Wassergehalt der Betonmischung mit hoher Genauigkeit auf wirtschaftliche Weise zu messen, zu steuern und zu registrieren.

Die Messung des Wassergehaltes einer Probe erfolgt auf der Grundlage der Moderation schneller Neutronen an Wasserstoffkernen. Die von der Strahlungsquelle emittierte energiereiche Neutronenstrahlung hat ein großes Durchdringungsvermögen durch Stoffe gleich welcher Art, weil keine Energie durch Ionisation verloren geht. Ein Energieverlust entsteht nur durch Stöße an andere Atomkerne, der umso größer ist, je mehr die Masse des Stoßpartners der Masse des Neutrons gleicht.

Da nun die Masse eines Wasserstoffatoms etwa gleich ist der Masse eines Neutrons, ist der Energieverlust bei Kollosionen mit Wasserstoff-Atomen am größten. Hier tritt die stärkste Moderation (Abbremsung) der Neutronenenergie ein.

Die gestellte Aufgabe wird dadurch gelöst, daß entweder von

fachheit in Anbau und Anwendung der gesamten Meßeinrichtung und der Steuerorgane; das Vorliegen der gesamten Verfahrensausrüstung im Baukastensystem, was leichte Austauschbarkeit der Einzelteile und bequeme Zugänglichkeit für Montage und Reparatur bedeutet. Die Betonqualität läßt sich mit einer bisher nicht erreichbaren Gleichmäßigkeit und Zielsicherheit steuern und außerdem noch laufend beweiskräftig aufzeichnen.

Weitere Merkmale der Erfindung sind Gegenstand der Ansprüche 3 bis 6.

Anhand der in der beiliegenden Zeichnung dargestellten einzigen Figur wird ein Ausführungsbeispiel beschrieben: Im Mischtrog der Mischmaschine (6) befinden sich Zement und Zuschlagstoffe in den vorgesehenen Anteilen / Mischung und eine bestimmte Mindestwassermenge aus dem Leitungsnetz (8), die über den Zulauf (4a) der Mischung beigegeben wird, deren Wassergehalt (Eigenfeuchte der Zuschlagstoffe + Mindestwasser) noch deutlich unter dem Sollwert liegt. Unter dem Mischtrog (6) ist die Strahlungsquelle (1) und der Detektor mit Vorverstärker (2) angeordnet. Während die jetzt noch etwas zu trockene Mischung durchgearbeitet wird, läßt sich die Wasserstoff-Atomkonzentration durch (1) und (2) messen, die vorverstärkten Impulse werden an den Impulsintegrator und Steuerspannungsgeber (3) weitergegeben. Dieser setzt die Impulse pro Zeiteinheit in elektrische Signale um, die sowohl an den elektrischen Wasserdoseur (4) für die Bemessung der Korrekturwasser-Zugabe zur Mischung über den Zulauf (4b) bis zum vorgesehenen Sollwert des Wassergehalts / Mischung gehen, als auch zur Steuerung des elektrischen Schreibgerätes (5) dienen.

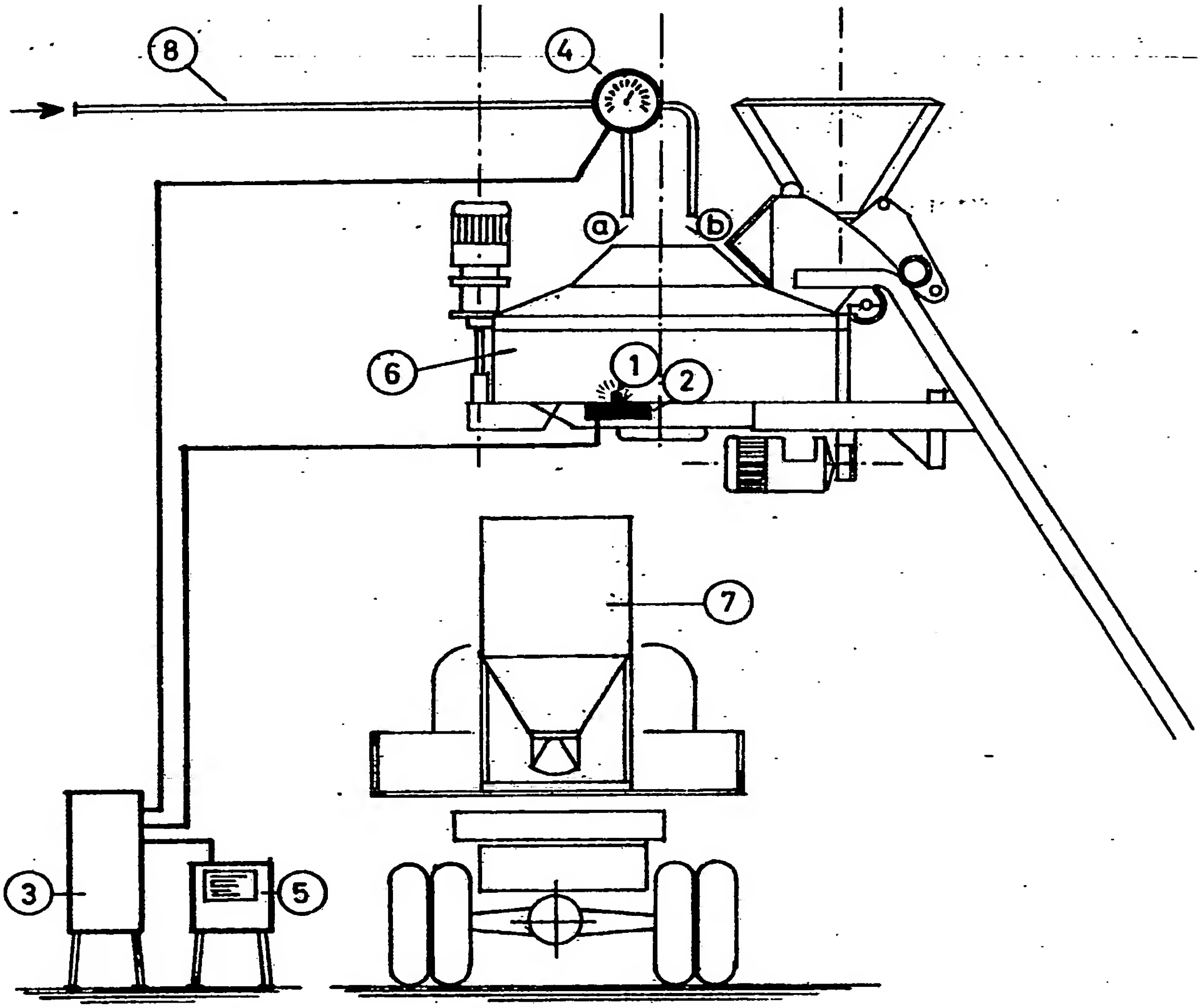
Wird zwischen dem Auslauf der Mischmaschine (6) und dem Transportgefäß (7) für den fertigen Beton ein Zwischensilo eingeschaltet, befinden sich die Strahlungsquelle (1) und der Detektor (2) als Sonde zusammengefaßt dort im zu untersuchenden Mischgut. Die Weitergabe und Verwertung der erhaltenen Meßwerte erfolgt wie oben beschrieben.

Joachim Toll.

7. Verfahren nach einem der Ansprüche 1 bis 5, dadurch gekennzeichnet, daß die Wasserdosierung elektrisch erfolgt.

8. Verfahren nach einem der Ansprüche 1 bis 7, dadurch gekennzeichnet, daß die Meßergebnisse und Steuervorgänge auf einem an sich bekannten Schreibgerät (5) laufend beweiskräftig festgehalten werden.

Joachim Folk



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Method for measuring and controlling the water content in fresh concrete

The invention relates to a method for measuring and controlling the water content in fresh concrete during production without interrupting the mixing process.

As is known, concrete is produced from the components cement, aggregate and water. It is difficult to define the water component here since aggregates are subject to large fluctuations in their own moisture content, which is difficult to ascertain and may substantially alter the water content of the concrete.

According to Abrams, the compressive strength D of concrete is established as a function of cement quality, type and quantity of the aggregates, external factors affecting the concrete, age of the concrete and water content, from the equation

$$D = \frac{A}{B^x}$$

where D indicates the compressive strength of the concrete, A and B are coefficients which take into account the factors mentioned (but which are constant in any given case) and x the water/volume of cement ratio. From this it clearly follows that the parameter x, which expresses the water/cement ratio (indicated in what follows by the abbreviation WCR) represents the

sole and all-important criterion for concrete quality. If the WCR is measurable and therefore known, the concrete quality to be expected is also known; if it can be kept constant, the concrete quality is also constant. Quality then depends only on processing factors, though these lead to substantially smaller variations in the resulting strength than fluctuations in the WCR.

Methods in which the water content in fresh concrete is measured indirectly during production (these measure the properties of the concrete mix which change with water content) are already known. One of these methods measures the resistance presented by the fresh concrete mix to an electrical current within a specified measurement section. The electrical conductivity depends on the moisture content of the sample within the measurement section between a pair of electrodes. A disadvantage here is the inevitable shortness of the measurement section, within which the temperature, homogeneity, structure, grain size distribution, grain form and extraneous electrolyte content of the concrete mix considerably affect the test result and may even render this unusable. The same applies to another method in which the change in the dielectric constants with the degree of moisture is ascertained by capacitive measurements. In another method, the consistency and plastic properties of the mix, which vary with water content, are utilised by measuring the resistance of the mix to deformation to assess water content. This resistance is expressed in the higher or

lower power consumption of the mixer motor. The power consumption of the mixer motor is however also dependent on mains voltage variations and on interference from incidental factors such as jamming of gravel grains or machine faults. As with the other two mentioned, this method therefore yields values which are at best only rough indications.

The procedure for determining the moisture content of the aggregates before they are processed with cement and water and using the measured values found to control the addition of water to the mix is already known. With this method it is however necessary, to achieve a reliable result, to measure all grain groups separately, which, because of the large number and complexity of the equipment then required, is uneconomic.

The invention therefore addresses the problem of measuring, controlling and recording the actual water content of the concrete mix with great accuracy and in an economic manner. The water content of a sample is measured on the basis of the moderation of fast neutrons on hydrogen nuclei. The high-energy neutron radiation emitted by the radiation source has high penetrative power through materials of whatever type because no energy is lost through ionisation. Energy loss occurs only through impacts with other atomic nuclei, and is greater the more nearly the mass of the other particle involved in the impact equals the mass of the neutron.

Since the mass of a hydrogen atom is approximately equal to the mass of a neutron, the energy loss is greatest in collisions with hydrogen atoms. In such cases, the greatest moderation (deceleration) of the neutron energy occurs.

The problem addressed is solved either by measuring from the outside, without interrupting the mixing process, through the walls of the mixing trough, the hydrogen atom concentration in the mix after neutron bombardment from a radiation source of appropriate strength by counting the moderated neutrons in the detector and using the measured values found to trigger electrical processes for controlling water dosing and recording the water content of the mix currently in production, or by determining the water content of the mix immediately after completion upon leaving the mixing machine, on the same principle, the measured values obtained here being used to control the water dosing of the mix immediately following, while the recording relates to the water content of the measured finished mix. The latter test configuration still delivers greater accuracy in a statement concerning the water content of the sample investigated with a lower radiation intensity of the neutron source, because measurements can be taken directly in the mix product. On the other hand there have to be higher running costs because of the intermediate measurement silo required and the mix already completed can no longer be corrected, disadvantages which can be avoided with the

first test configuration. Here the radiation source must be fitted at a point below the mixing trough which is covered by as deep a layer of concrete as possible, which does not need to be stationary but can continue to be processed during the measurement. Prerequisites for reproducible test results are a powerful radiation source, a sensitive detector and mixing drum filling as uniform as possible in terms of quantity. The continual changes in the degree of compaction of the mix product caused by the mixing process are adjusted statistically during the pulse count. The pulse rate, the aim naturally being to make this as high as possible, is used for control and recording processes after it is converted into electrical quantities (current and voltage values)

The advantages obtained with this radiometry method are: measurement of the water content of the fresh concrete with an accuracy never before achieved, with a maximum measurement uncertainty of ± 0.25 % by volume relative to the fully compacted concrete; pronounced control voltages which can be used to control an electric water dosing unit and which, transmitted to a recording device, open up the possibility of continuous and uninterrupted proof of quality of the entire concrete production; simplicity in the construction and use of the entire measurement installation and controls; modular design of the entire equipment for implementing the method, which means easy replacement of the individual parts and ease of access for fitting and repair. Concrete quality can be controlled with a

uniformity and certainty never before achievable and moreover can be continuously recorded to provide a conclusive record.

Further characteristics of the invention are given in claims 3 to 6.

With reference to the single figure shown in the appended drawings, an example of an embodiment is described: in the mixing trough of the mixing machine (6) there are cement and aggregates in the specified proportions for each mix and a specified minimum quantity of water from the pipe network (8) which, via the feed (4a), is added to the mix, the water content of which (moisture content of the aggregates themselves plus minimum water) is still clearly below the desired value. Below the mixing trough (6) is arranged the radiation source (1) and the detector with preamplifier (2). While the mix, still somewhat too dry, is worked thoroughly, the hydrogen atom concentration can be measured by (1) and (2), and the preamplified pulses are passed to the pulse integrator and control voltage sensor (3). This converts the pulses per unit time into electrical signals which go to the electric water dosing unit (4) for measuring the water to be added via the feed (4b) to correct the mix until the desired water content value for each mix is reached, and are also used to drive the electrical recording device (5).

If an intermediate silo is placed between the outlet of the mixing machine (6) and the container (7) for

transporting the finished concrete, the radiation source (1) and the detector (2) are combined as a probe at that point in the mix product to be tested. The measured values obtained are transmitted and analysed as described above.

Claims

1. A method for measuring and controlling the water content in fresh concrete during production without interrupting the mixing process, characterised in that the hydrogen atom concentration in the mix after neutron bombardment from a suitably powerful radiation source is measured from outside through the wall of the mixing trough (6) by counting the moderated neutrons in the detector and using the measured values found to trigger electrical processes for controlling water dosing and recording the water content of the mix currently in production.

2. A method for measuring the water content in fresh concrete immediately after production and for controlling the water content of the mix immediately following characterised in that the hydrogen atom concentration in the first mix is determined by radiometry in a measurement silo as in the method according to claim 1 and, using the measured values found, electrical processes are triggered for controlling the water dosing of the mix immediately following and recording the water content of the first finished mix investigated.

3. A method according to claim 1, characterised in that an americium/beryllium package with a radiation intensity of at least 1000 milli-Curie (mCi) is used as a radiation source (1).

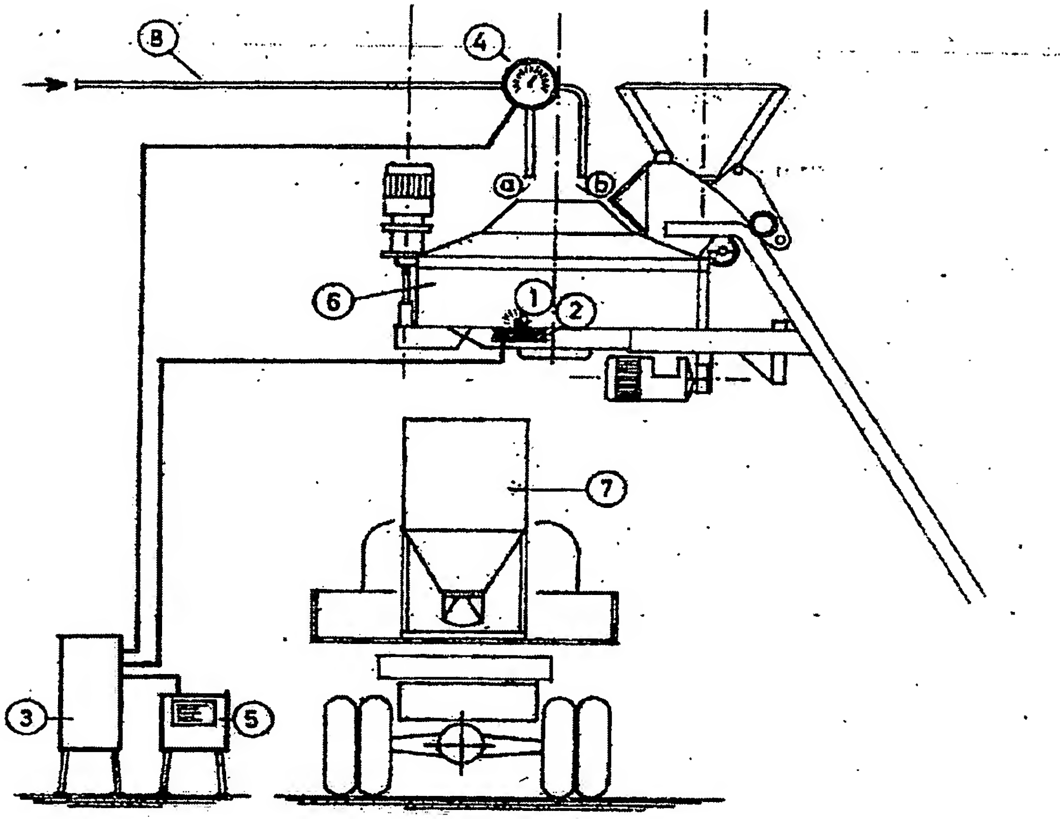
4. A method according to claim 2, characterised in that an Am-241/Be package with a radiation intensity of approximately 100 mCi is used as a radiation source (1).

5. A method according to claim 2, characterised in that a container of at least 200 litres capacity but at most to take a single mix batch is used as a measurement silo.

6. A method according to claim 1 or 2, characterised in that a considerable number of proportional counter tubes with boron trifluoride (BF_3) under pressure are used as a detector (2).

7. A method according to any one of claims 1 to 5, characterised in that water dosing is carried out electrically.

8. A method according to any one of claims 1 to 7, characterised in that the measurement results and control processes are stored continuously on a recorder (5) known in itself, as a conclusive record.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